

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

**APPLICATION FOR LETTERS PATENT**

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**SYSTEM FOR DAMPING OSCILLATIONS**

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System for damping oscillations

Background of the invention

1. Field of the Invention

0001 The invention relates to a system for damping oscillations in channels which carry fluid in a component, in particular coolant in cooling channels for an optical element, in particular in a projection exposure objective for semiconductor lithography.

2. Description of the Related Art

0002 Optical elements frequently need to be cooled owing to the radiation energy, in particular in semiconductor lithography using lasers which emit beams in the UV band. This applies, for example, to mirrors in EUV systems, which are provided, in their housing, with cooling channels through which a cooling liquid flows. This results in the heat being dissipated. However, one problem is that the flowing medium can lead to oscillations and natural frequencies resulting from possible turbulence, for example in the region of channel direction changes, which have a highly disadvantageous effect on the optical function of the entire optical system.

Summary of the Invention

0003 The present invention is thus based on the object of achieving a system for overcoming or at least damping oscillations in or through channels which carry fluid, in such a manner that the flowing medium does not cause any negative effects.

0004 According to the invention, this object is achieved by the following steps:

- a) oscillations that occur being detected by sensors,
- b) after the detection the results are supplied in the form of a control loop to actuators,
- c) the actuators are piezoelectric elements in the form of thin plates, films or layers and
- d) by activation of said actuators oscillations are produced, which are in antiphase to the oscillations produced by turbulence in the fluid, and whose frequency and amplitude are at least approximately the same.

0005 According to the invention, piezoelectric actuators in the form of thin plates, films or layers can now be used in conjunction with a control loop, for example an adaptronic control loop, in which sensors detect the oscillations, and the oscillations are signaled via a computation unit for evaluation to the piezoelectric actuators, so that the latter are activated appropriately and can produce oscillations and frequencies which counteract oscillations and natural frequencies produced by turbulence.

0006 According to the invention, both the piezoelectric actuators and the sensors are integrated in the component, for this purpose.

0007 In principle, the most widely differing types of sensors can be used for detection of the oscillations that occur. In one very advantageous embodiment of the invention, however, piezoelectric sensors are likewise used for this purpose, and are advantageously arranged alternately in the region of the turbulence zones, for example channel direction changes.

0008 Although, in principle, the use of piezoelectric elements, such as piezo stacks, in optics is already known from US 4,202,605 and US 4,295,710, in which piezo stacks are used for setting faceted mirrors, for use in the form of plates, films or layers in an

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adaptronic control loop with sensors and actuators is, however, novel, and represents a solution that is not obvious.

0009 An exemplary embodiment of the invention is described in principle in the following text, with reference to the drawing.

Brief description of the drawings

0010 Figure 1 shows a detail of a mirror with a cooling channel in the corner region; and

0011 Figure 2 shows a detail of a cooling loop or a cooling tube.

Detailed description

0012 The invention will be described in the following text with reference to a mirror in an EUV system with a projection exposure objective for semiconductor lithography. However, of course, the invention can also be applied to other fields of optics, and can also be used in other areas.

0013 The EUV radiation from a beam source causes heating in the mirror. For this reason, it is known for the mirror 1, which is arranged, for example, in a projection exposure objective 1a (indicated only by dashed lines) to be provided with cooling channels 2, in which a cooling medium circulates. Even if attempts are made to force the cooling medium to circulate with a laminar flow, it is not always possible to avoid turbulence occurring. This is particularly true in the region of channel direction changes 3. Figure 1 shows a laminar flow on the input side, and a turbulent flow 4 in the area of a direction change, which may once again be followed by a laminar flow. The turbulent flow 4 causes the mirror 1 to oscillate, resulting in changes to the

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optical path length, which can lead to corresponding imaging errors. This means that, in order to avoid such imaging errors, it is necessary to avoid the oscillations that occur, or at least to considerably counteract them. This is done by using counter measures in those areas in which the greatest deformations caused by oscillations occur.

0014 To this end, it is necessary to detect the oscillations, in a first step. This is done using sensors in the form of piezoelectric elements 5, which are arranged or integrated in the mirror 1 in the region of the direction change 3. The oscillations lead to the production of electrical voltages in the piezoelectric elements, owing to the length changes, and these electrical voltages are passed via control lines 6 (only one is illustrated in Figure 2, by way of example) to a computation and evaluation unit 7. Depending on the magnitude and form of the oscillations, voltage pulses are passed to actuators 9, in the form of piezoelectric elements, via control lines 8 from the computation and evaluation units 7. The application of the voltages leads to length changes in the piezoelectric elements that are used as actuators 9. The essential feature is now that the pulses introduced via the control line 8 stimulate the piezoelectric elements 9 such that "opposing oscillations" occur, whose magnitude and form, i.e. whose frequency and amplitude compensate for, or at least considerably damp, the oscillations occurring due to the turbulent flow.

0015 The piezoelectric elements can be arranged alternately as sensors 5 and as actuators 9 in the mirror 1.

0016 The arrangement of the piezoelectric elements 5 and 9 is governed by the physical characteristics. Thus, for example, they can be arranged on the outside of the cooling channels 2 in the mirror 1, or else in the

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cooling channel 2 itself, as is indicated, for example, in the form of a dashed line by 9' in Figure 1. The piezoelectric elements 5 and 9 can likewise also be bonded directly onto the outside or inside of a cooling loop 10.

0017 The piezoelectric elements are fitted or introduced into the structure or mirror 1 in the form of very thin-walled plates, films or layers.

0018 It is also possible to provide for all the piezoelectric elements 5, 9 to be configured as sensors 5 in the quiescent state or in a phase with only minor oscillation excitation. In this way, all the elements detect disturbances, after which, by means of an appropriate control system, only individual, specific piezoelectric elements or, if necessary, even all the piezoelectric elements, are then activated as actuators 9. The advantage of this configuration is that there is then no need to assign specific piezoelectric elements as sensors or as actuators.